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## (54) Portable machine tool

(57) The machine tool (10), particularly for machining the fan seal lining (24) of a gas turbine engine (12), comprises a rotatable arm (26), mounted on a shaft (16) of the engine (12). The arm (26) is driven by an electric motor (160) through a gear box (162) attached to a free standing power unit (138). The arm (26) has a machining head (30) with a cutting tool. A guide plate on the head is contacted by a follower movable axially with the cutting tool to cause it to follow a profile formed on the guide plate to cut the profile in the lining (24). The tool is manually radially adjusted and motor driven axially. A seal box (36) around the tool is coupled in the arm interior and other passages to a suction device. The head has a gauge assembly for contacting the lining (24).

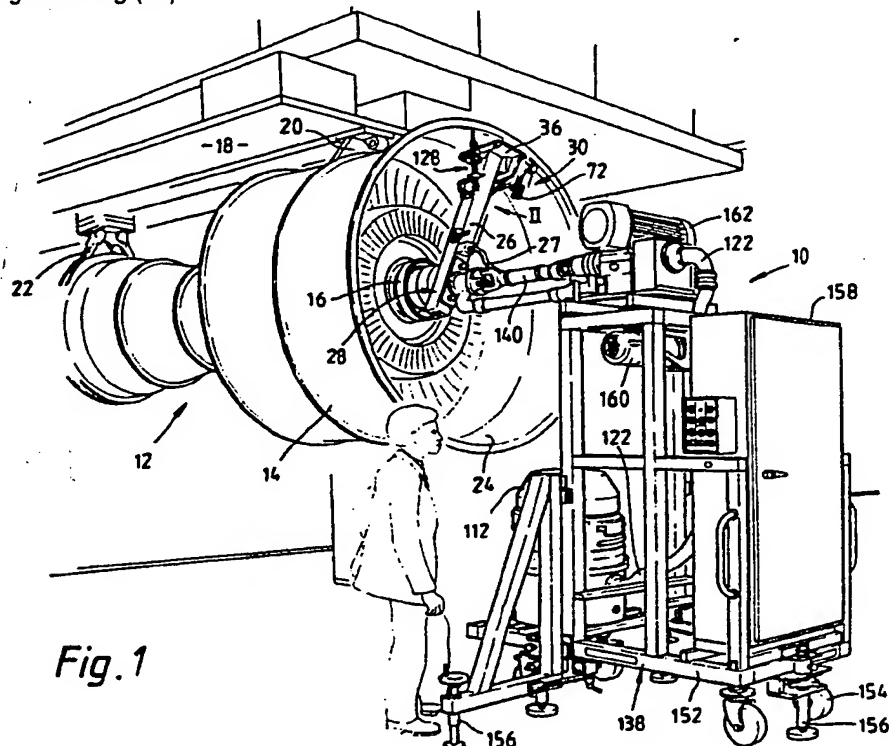


Fig. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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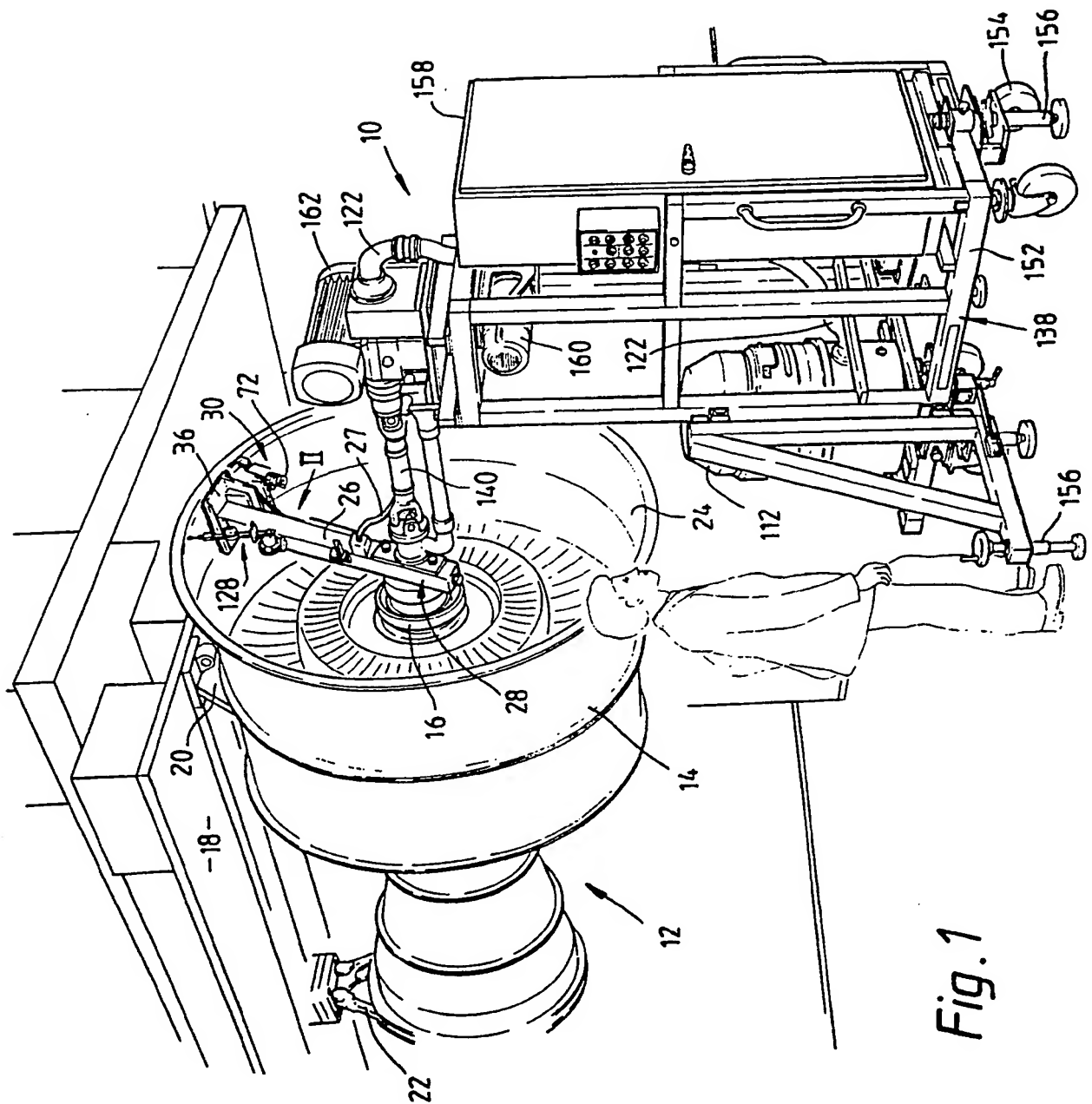
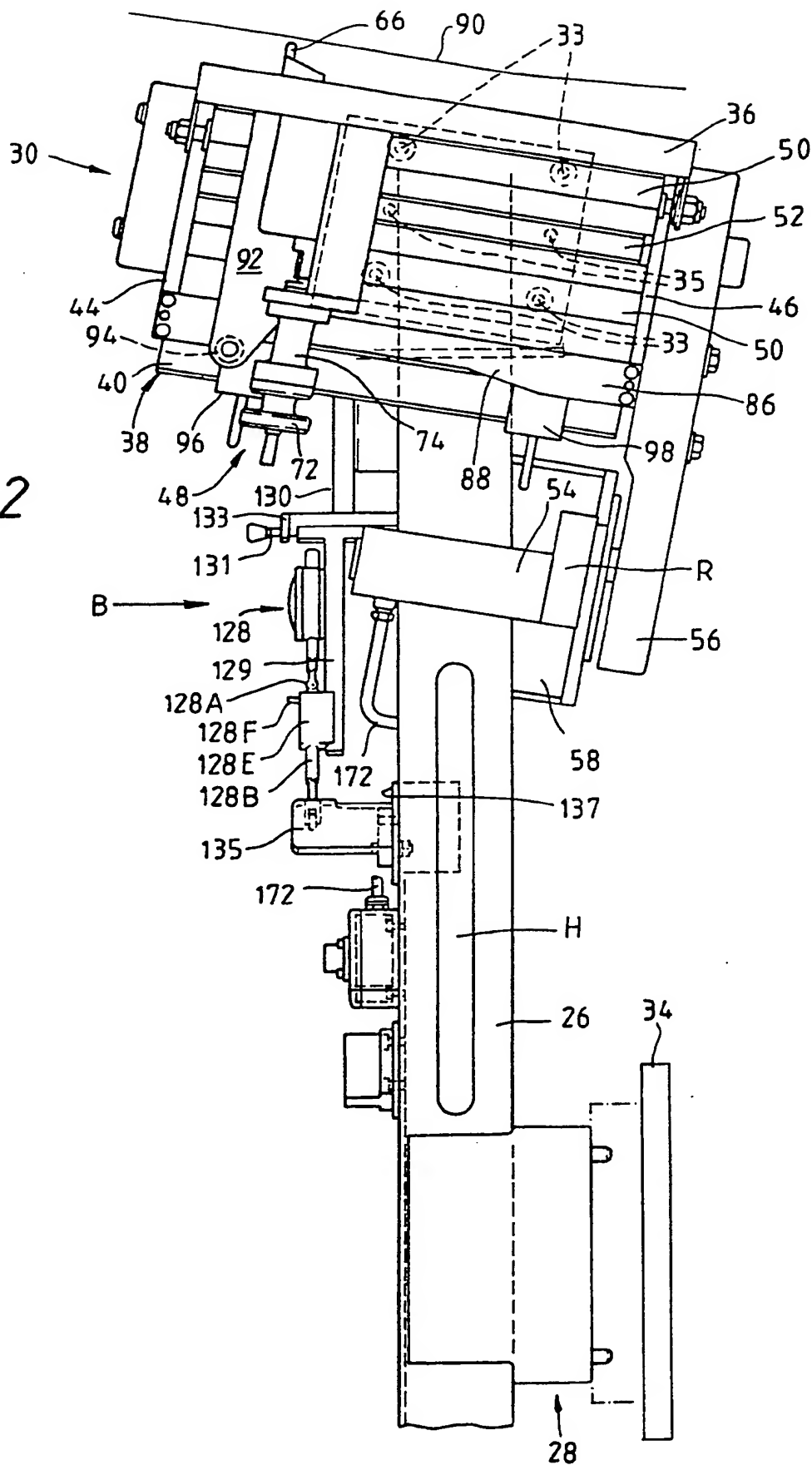
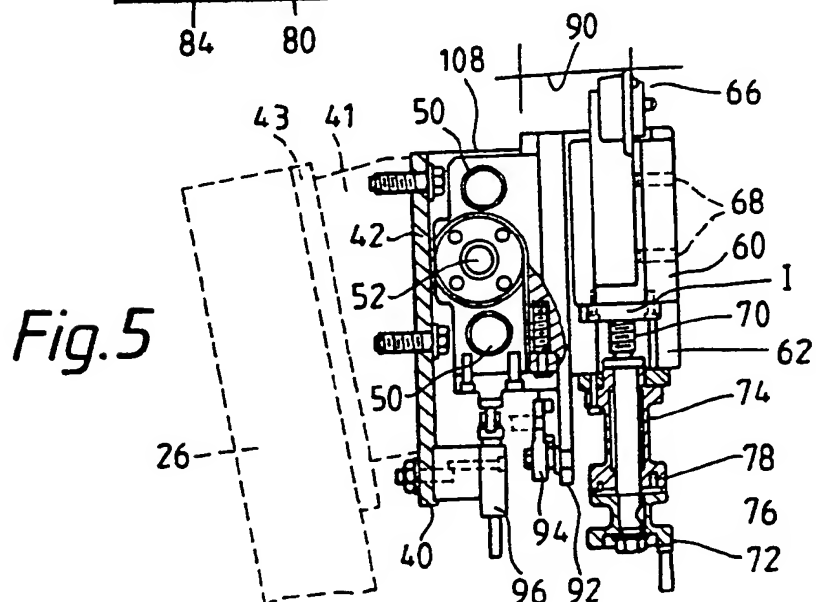
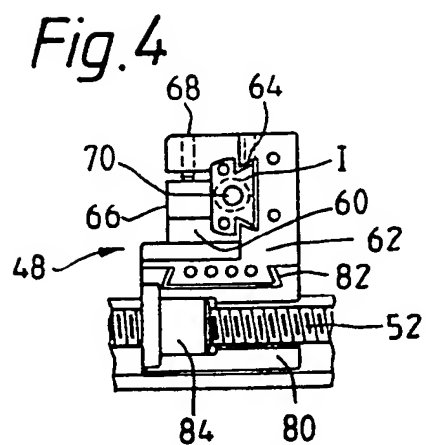
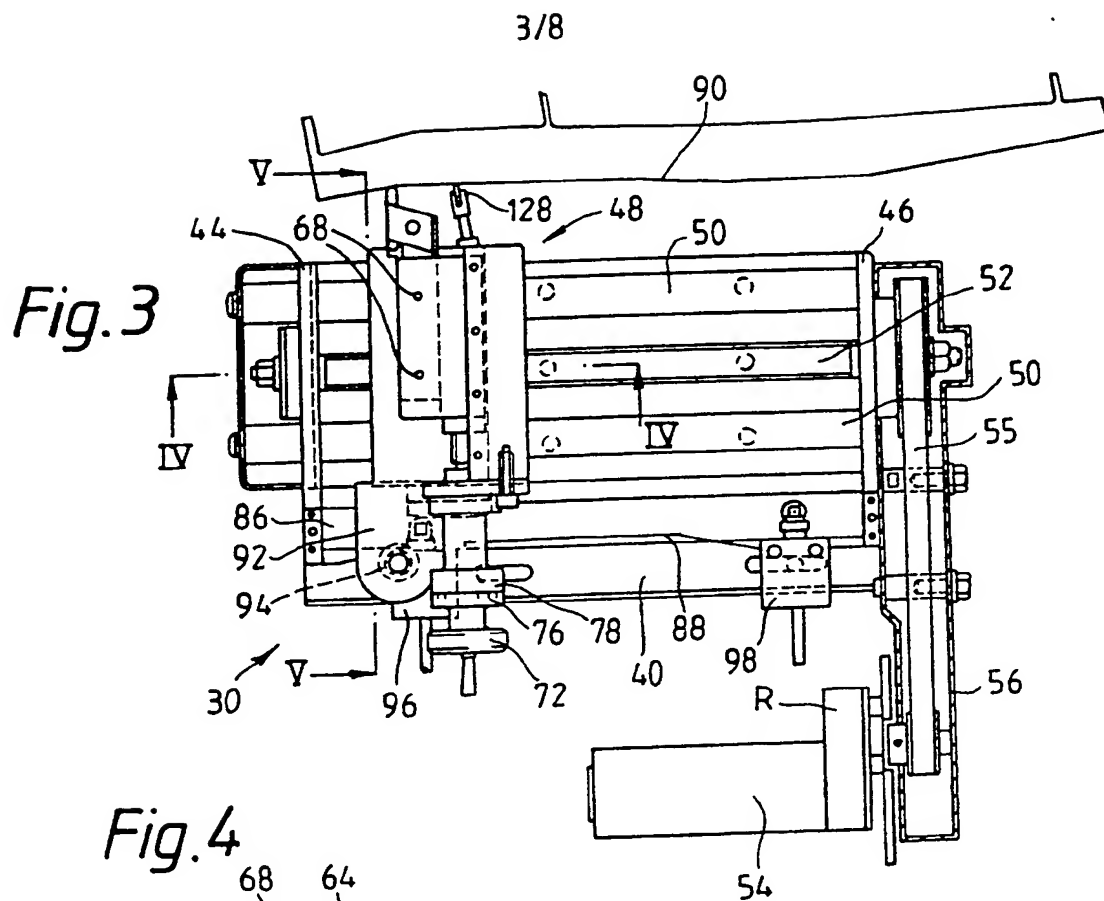
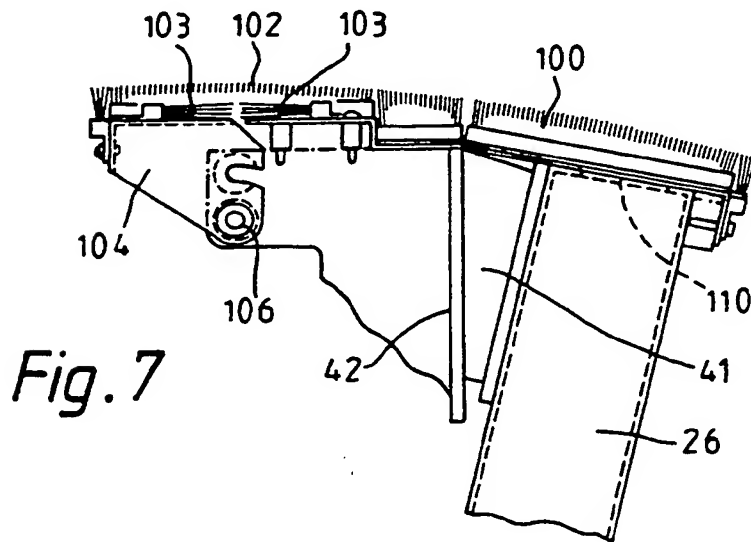
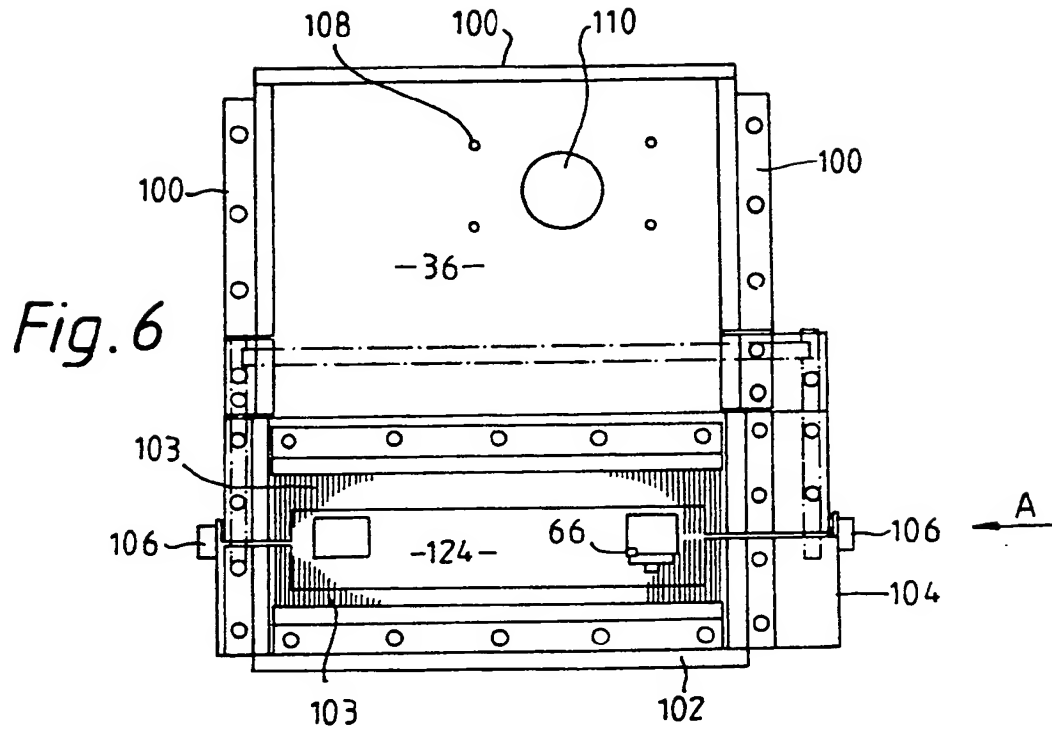
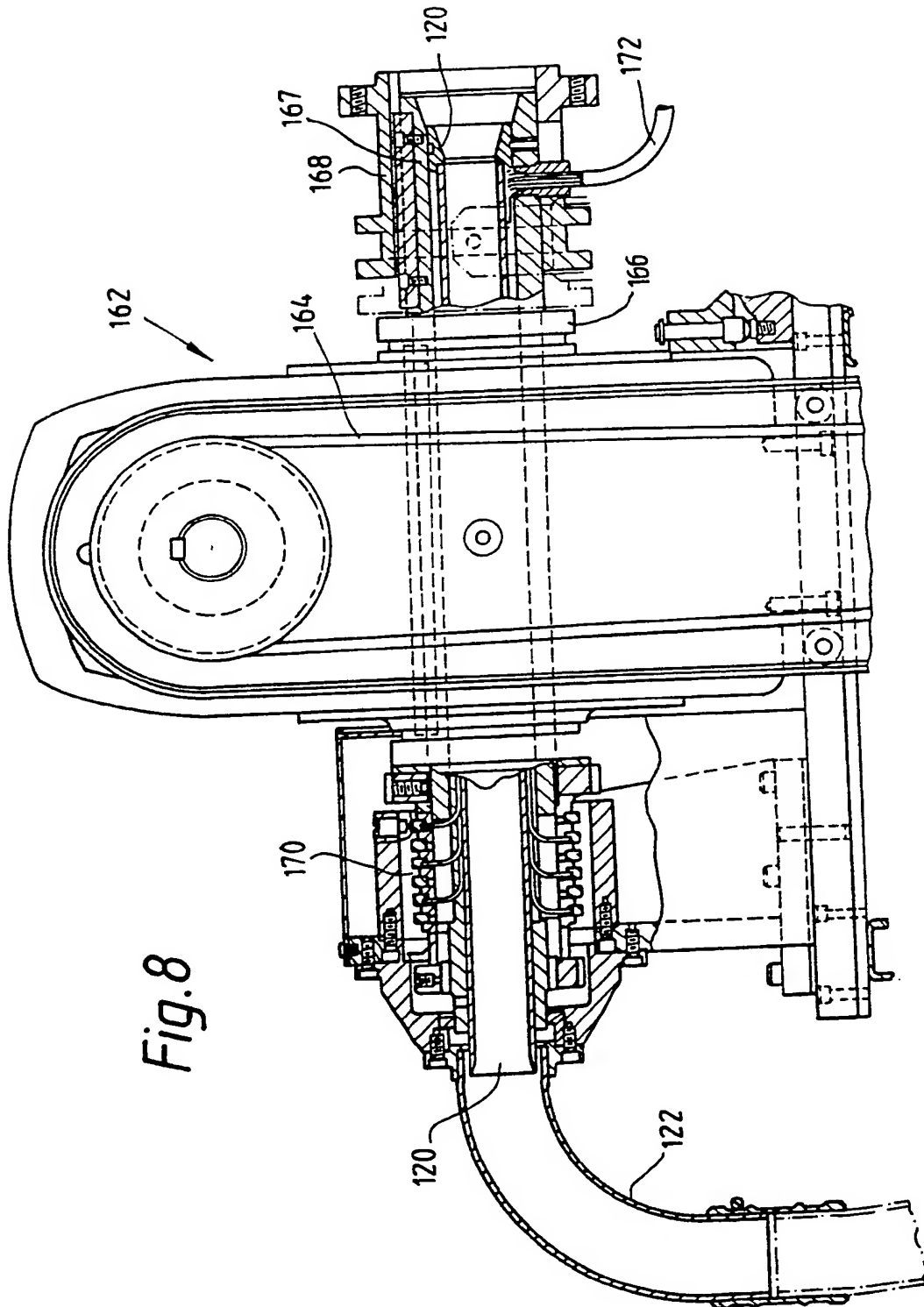


Fig. 2









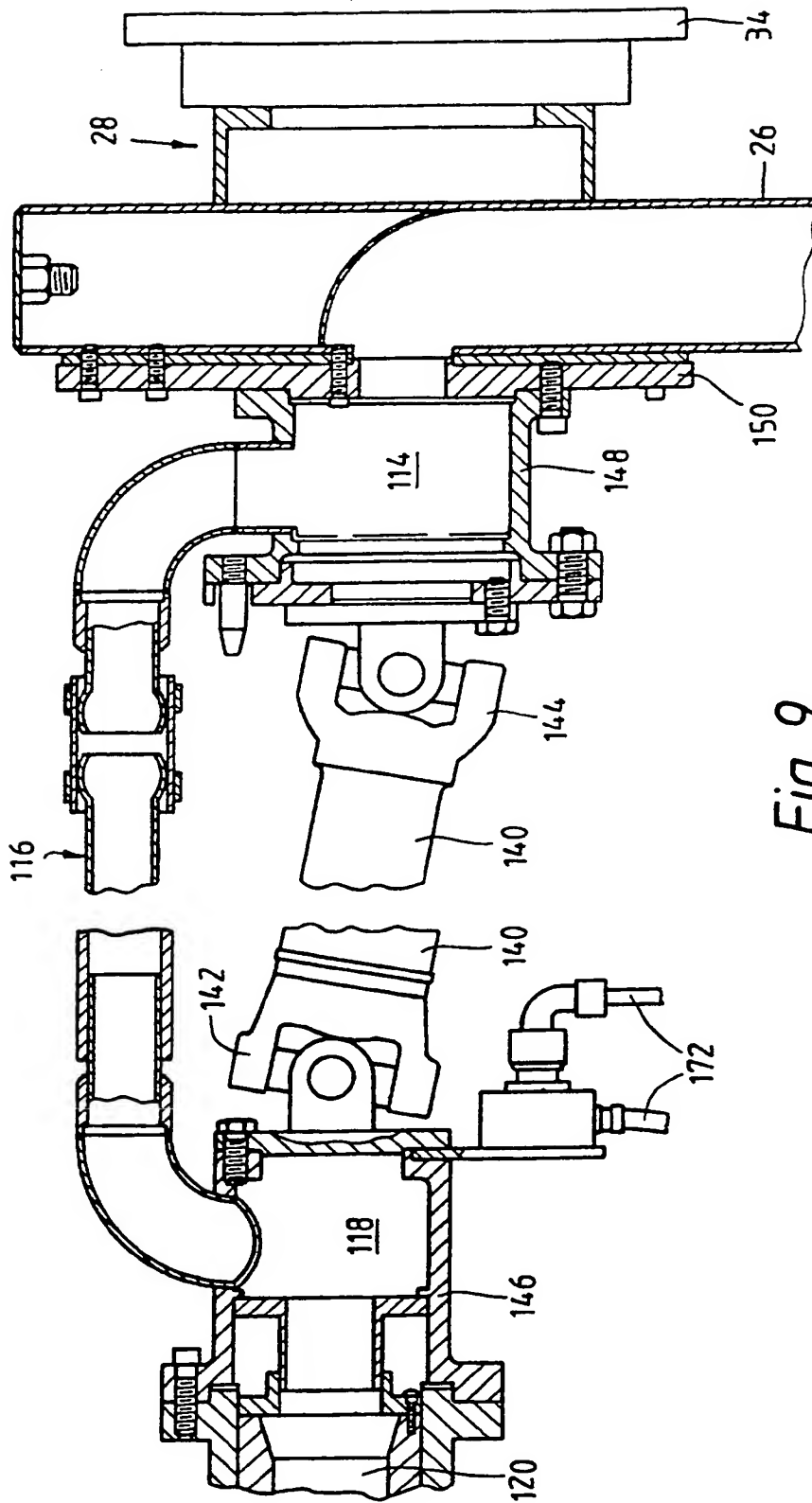
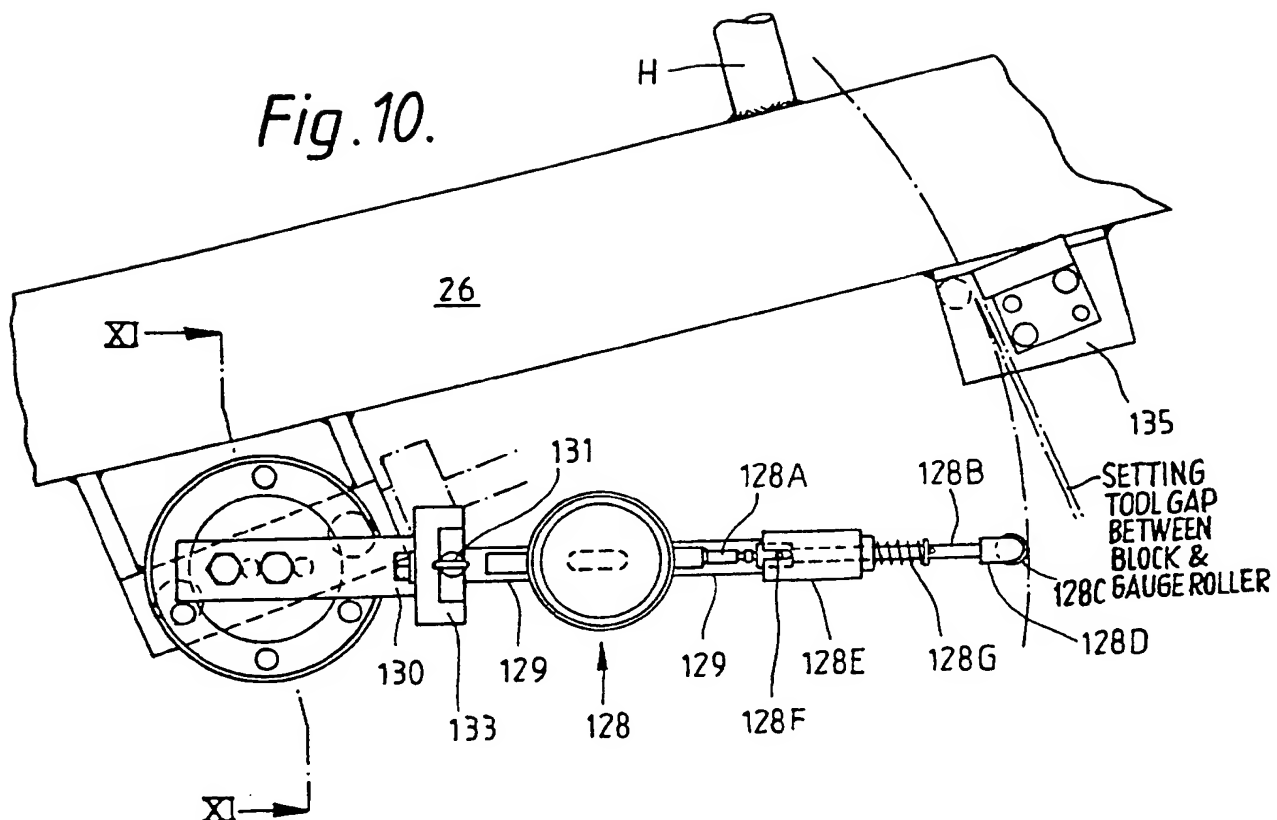
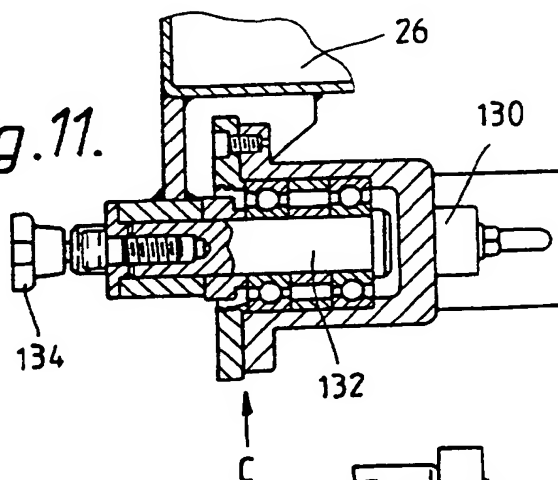
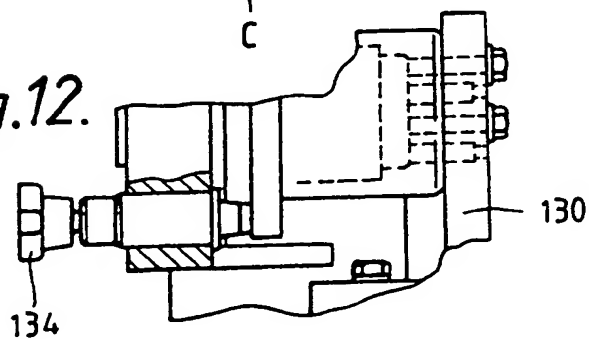


Fig. 9

*Fig. 10.**Fig. 11.**Fig. 12.*



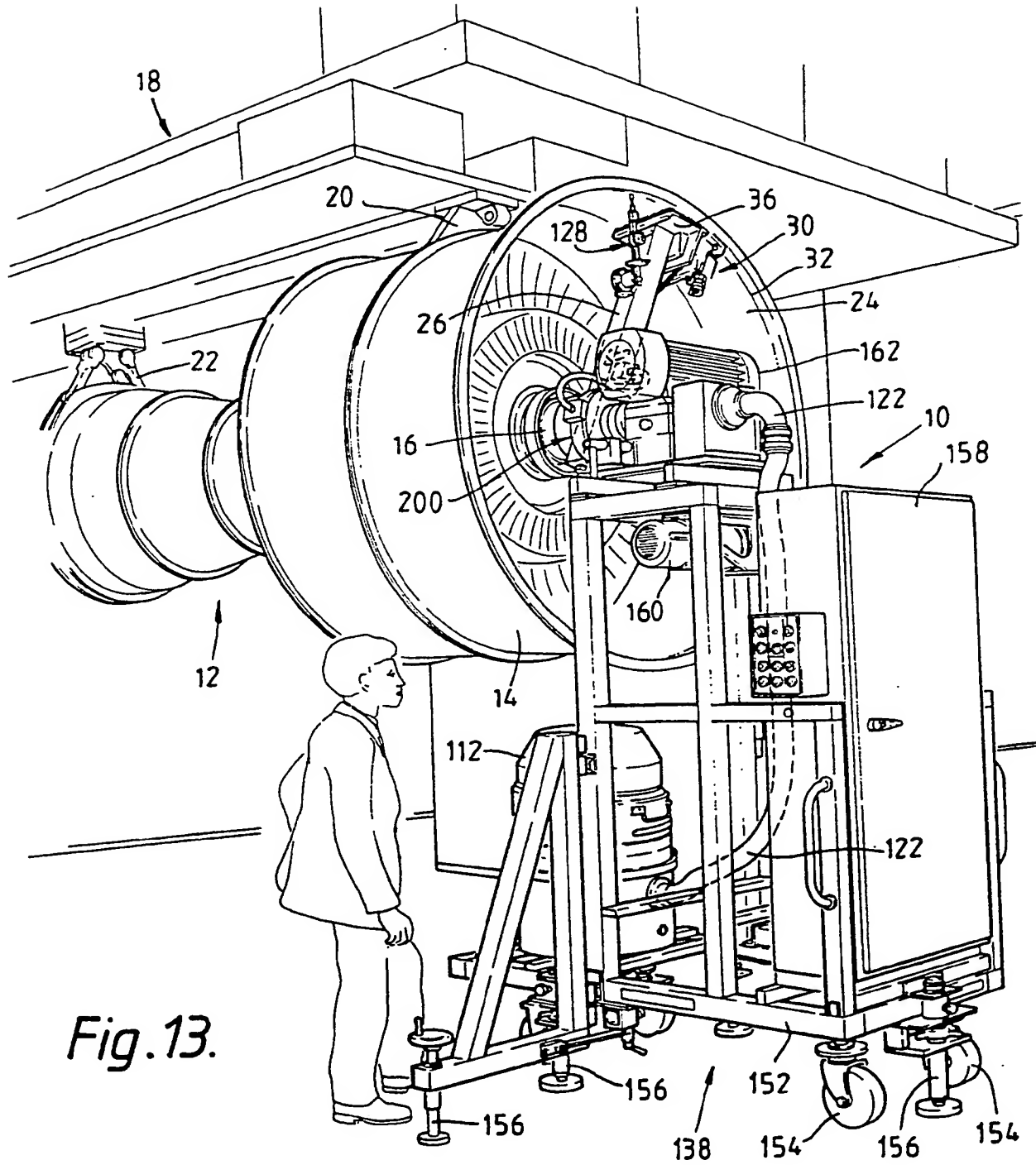


Fig.13.

IMPROVEMENTS IN OR RELATING TO MACHINE TOOLS

This invention relates to machine tools, particularly machine tools which can be transported and attached to a workpiece for machining operations to be performed.

Transportable machine tools are frequently used where it is more convenient to take the tool to the workpiece, because the workpiece is large and heavy and cannot be readily attached to a static machine tool for removal of material.

For example, in the case of modern gas turbine engines which have a large diameter bladed fan driven by a core engine, the fan rotates in a casing having a fan seal lining made of abradable material. The casing can be many feet in diameter, and the clearance between the tips of the fan blades and the seal lining has to be as small as possible in the operating condition to maximise engine efficiency. It is necessary to machine the fan seal lining to the correct diameter when the engine is not operating in order to ensure attainment of an optimum operating clearance, and this may not be easy or even possible on a static machine tool because of the large diameter of the fan casing.

Also, when the engine is mounted on an aircraft, the fan casing will distort slightly so that the fan seal lining will not be exactly circular. It is therefore desirable to machine the fan seal lining with the engine suspended in the same manner as it would be on an aircraft.

The present invention seeks to provide a machine tool which can be attached to a workpiece, e.g. an aircraft engine, in order to machine a surface of the workpiece, e.g. a fan seal lining.

Accordingly, the present invention provides a transportable machine tool, comprising an arm having mounting means arranged to enable the arm to be rotatably mounted in relation to a workpiece, the rotatable arm having a machining head including at least one cutting

tool, cutting tool drive means arranged to drive the cutting tool relative to the rotatable arm, and further drive means arranged to rotate the arm relative to the workpiece.

The machining head can include a guide arranged to cause the cutting tool to follow a predetermined path corresponding to a profile to be cut on the workpiece.

The machining head can be provided with seals around its periphery to make a seal with the workpiece so as to prevent machining debris from escaping.

The machine tool can be provided with debris extraction apparatus, for example vacuum apparatus to extract the debris cut from the workpiece during operation of the machine tool.

The cutting tool drive means can comprise a motor, for example a variable speed electric motor, attached to the rotatable arm and arranged to drive a tool post on a lead screw.

The rotatable arm can support gauging means, e.g. a dial gauge arrangement, to enable the cutting tool to be correctly positioned relative to the workpiece, and to check a surface of the workpiece after the surface has been machined.

The further drive means for rotating the arm can comprise a freestanding transportable power unit including at least one motor, e.g. a variable speed electric motor, and a gearbox driven by the motor, the rotatable arm being driven by an output shaft of the gearbox, preferably through a disconnectable coupling adapted to allow misalignment between the drive means and the rotatable arm. The variable speed of the electric motor allows different cutting speeds to be adopted.

The rotatable arm of the machine tool can be attached by means of an adaptor arrangement to the end of a fan shaft of a gas turbine engine, and caused to machine a desired profile of the fan seal lining whilst the engine is mounted in a manner corresponding to that in which the

engine would be mounted in an aircraft. In fact, it would be possible, assuming the availability of a suitable power supply, to machine the desired profile whilst the engine is still installed on the wing of an aircraft.

Exemplary embodiments of the present invention will now be more particularly described with reference to the accompanying drawings, in which,

Figure 1 is a perspective view of a preferred form of machine tool according to the present invention secured to a suspended gas turbine engine;

Figure 2 is an elevation of a rotatable arm and machining head of the machine tool shown in Figure 1, as viewed on arrow II in Figure 1;

Figure 3 shows the machining head of Figure 2 partly cut away to reveal greater detail;

Figure 4 is a part section on line IV-IV in Figure 3;

Figure 5 is a section on line V-V in Figure 3;

Figure 6 is a view on the end of the machining head shown in Figures 2 to 5;

Figure 7 is a view on arrow 'A' in Figure 6;

Figure 8 is a part sectioned elevation showing the gearbox and drive shaft of the machine tool power unit;

Figure 9 shows the power transmission shaft of the machine tool;

Figure 10 is a view on arrow B in Figure 2;

Figure 11 is a section on line XI-XI in Figure 10;

Figure 12 is a view on arrow C in Figure 11;

Figure 13 is a view similar to Figure 1 but showing an alternative form of the machine tool.

Referring to the drawings, Figure 1 shows a transportable machine tool 10, attached to an aircraft engine 12. The engine 12 includes a fan casing 14 and a fan shaft 16, and is suspended from a support structure 18 by a front yoke 20, and a pair of rear links 22.

A fan seal lining 24 of an abradable plastics material is provided on the internal surface of the fan casing 14 in the plane of the blades of a fan rotor which

will be fitted to the end of the shaft 16 after the machining operation is finished. The seal lining 24 is profiled by the machining operation, as will be described further below, to match the design specification for the fan blade tip-to-lining gap in the static and low rotational speed conditions.

The machine tool 10 comprises an arm 26 (see also Figure 2) having mounting means 28 at one end and a machining head 30 at the other end, positioned so as to be adjacent the seal material which is to be machined. Machine tool 10 also comprises a free-standing drive unit 138 comprising a transportable frame or carriage.

As best shown in Figure 2, the mounting means 28 includes a flange 34 for attachment to an adaptor (not shown) to enable the mounting means to be secured to a CURVIC (Trademark) coupling on the fan shaft 16, which would normally take the fan rotor.

Referring to Figures 2 to 5, the machining head 30 is mounted at the opposite end of the arm 26, and besides a seal box 36 to be described later, also comprises a tool slide assembly 38 attached to a wedge-shaped light alloy block 41 (Figure 5) by bolts 33 passing through a base plate 40 of the assembly 38. In turn, the block 41 is attached to a sole plate 43 which is welded to the arm 26. Dowels 35 are also provided to locate the base plate 40 accurately with respect to the block 41 before inserting the bolts 33. The base plate 40 is secured to side plates 44, 46 (see particularly Figures 2 and 3). A tool post 48 is mounted in the slide assembly 38 on two guide bars 50 which are secured between the side plates 44, 46. The tool post 48 is also driven axially by a lead screw 52 which is rotatably mounted in rolling element bearings (not shown) in the side plates 44, 46, the lead screw being driven by an electric motor 54 through a reduction gearbox R and a belt 55 with pulleys which are enclosed in a cover 56 (see Figure 3). The motor 54 is bolted to a support bracket 58 which is secured to the arm 26.

A handle H is provided on the side of the arm 26 to aid in manual positioning of the arm.

The tool post 48 carries a tool 66, which is attached to a first radial slide 60 (see particularly Figures 4 and 5) which is mounted in a second radial slide 62 having a guide 64. The cutting tool 66 is clamped to the slide 60 by set screws 68. The first radial slide 60 has an insert I with a threaded bore which is engaged by a lead screw 70 operated by a handle 72, the lead screw 70 being rotatably located in a mounting 74 attached to the second slide 62. The handle 72 has a scale 76 located adjacent a fixed scale 78 on the mounting 74 to provide fine radial adjustment for the cutting tool 66.

The second radial slide 62 is mounted in a base 80 having a guide 82, the lead screw 52 engaging a nut 84 in the base 80. A guide plate 86 (Figure 2) is secured between the side plates 44, 46 and has a profile 88 corresponding to a profile 90 which is to be machined in the seal material. The second radial slide 62 has an extension arm 92 to which is rotatably attached a follower wheel 94. The slide 62 is biased so that the wheel 94 is urged into contact with the profile plate 86, thereby causing the cutting tool 66 to follow the correct path when the tool post 48 is driven by the lead screw 52.

Two micro-switches 96, 98 are secured to the plate 40, each being operable on contact by the tool post to switch off the motor 54, thereby limiting the traverse of the tool post in both directions. Both micro-switches are adjustable in position axially of the base plate 40 in order to ensure that the cutting tool performs the full stroke at each end of its traverse.

Referring particularly to Figures 6 and 7, the seal box 36 is shaped to conform generally to the internal shape of the face casing. It has brush seals 100 on three sides, and brush seals 102 on a housing 104 which is pivotable on pins 106. The top of the seal box 36 has an opening 110 to provide communication with the hollow

interior of the arm 26. The interior of the arm communicates with a suction cleaner 112 (Figure 1) via a chamber 114 (Figure 9), a duct 116 which rotates with the arm 26, a chamber 118, a rotatable sleeve 120, and a static hose 122, which is attached to the suction cleaner 112. If the debris to be collected from the machining process is a health hazard, the suction cleaner should be constructed to meet B.S. 5415 Section 2:2, Supplement No. 1.

The seal box 36 (Figures 6 and 7) is attached to the arm 26 and the end plates 44,46 by any suitable means such as bolts or studs. The cutting tool 66 extends through an opening 124 in the seal box 36, so that the tool can contact the workpiece. The opening 124 is sealed by two further brush seals 103 (shown "ghosted" in Figure 6), which extend across the opening 124 to seal the tool path by preventing machining debris from falling through the opening, and enabling it to be extracted from the sealed space through opening 110 by the suction cleaner 112.

Referring to Figures 1,2,10,11 and 12 a dial gauge assembly 128 is pivotally attached to the arm 26. In Figures 1,3 and 10 to 12 it is shown in its operating position. Figure 2 shows it swung round to its non-operating or datum checking position. The dial gauge itself has an operating arm 128A provided with an extension 128B having a roller 128C attached to its end.

The dial gauge is attached to a support beam 129 which can be adjusted in the axial direction by engagement with two thumb screws 131, one of which is on the unseen side of the view in Figure 10. The thumb screws 131 are provided in end plates 133 of a housing 130 and allow the dial gauge assembly 128 to be fixed in an axial position which is determined by a gauge block (not shown) as described later.

The housing 130 is rotatable on a pivot shaft 132 attached to the arm 26. Two plungers 134 (Figures 11,12) enable the housing 130 to be locked in the operative or non-operative position.

The operating arm extension 128B is slidably held in a block 128E which is attached to the support beam 129. The end of the operating arm 128A is spring-biased onto the radially inner end of the extension 128B, which is shown projecting slightly from the end of the block 128E. A pin 128F projects from the radially inner end of the extension 128B (projecting out of the paper in Figure 10) and slides in a slot as shown in the block 128E. By pulling the pin 128F radially inwards against a compression spring 128G acting between extension 128B and block 128E and twisting the pin out of the slot, the extension 128B, with roller 128C, can be retracted slightly as required to ensure that the roller does not contact the fan seal lining at any other point when the gauge assembly 128 is swung from the operating to the non-operating position.

Referring particularly to Figures 1, 8 and 9, the machine tool 10 has a free-standing drive unit 138, a variable speed electric motor of which drives the arm 26 through a drive train including a transmission shaft 140, universal couplings 142, 144, sleeves 146, 148, and a plate 150 fixed to the inner end of the arm 26. The transmission shaft is provided with the universal couplings to allow for a considerable amount of misalignment (if necessary) between the drive unit 138 and arm 26.

The drive unit 138 comprises a framework 152 provided with castor wheels 154 and jacks 156. The wheels 154 enable the power unit 138 to be moved with ease, and the jacks enable the unit to be fixed in position relative to the workpiece.

The framework 152 supports the suction cleaner 112, a control cabinet 158 and the variable speed electric motor 160, driving a gear box 162 via a V-belt 164. It is important that the gearbox 162 is a worm-and-wheel type gearbox in order to prevent the weight of the arm 26 from causing it to rotate when the drive is switched off.



Note, however, that other means are known which could perform the same function. The gear box has a hollow output shaft 166 through which passes a drive shaft 167 connected to the sleeve 146 by a further sleeve 168. The two sleeves 146 and 168 are keyed together. The sleeve 168 is hollow and the duct 120 is secured within the shaft 167 so as to be rotatable with the shaft 166. The duct 120 serves to conduct waste material from the chamber 118 to the hose 122, and to prevent the waste material from interfering with slip rings 170. The slip rings 170 conduct electrical power via cabling 172 to the microswitches 96,98 and the electric motor 54 on the arm 26.

It should be noted that a short electrical connection 27 is provided between a junction box on the arm 26 and a junction box on a part of the drive unit to which the arm 26 is fixed. This is a safety feature and ensures that the transmission shaft 140 must be connected to the arm 26 before it can be rotated.

The control cabinet 158 controls the operation of the motor 160, the motor 54, and the suction cleaner 112.

In order to use the machine tool 10, the arm 26 is secured to the engine fan shaft 16 through flange 34. The drive unit 138 is then wheeled into position, and raised on the jacks 156, or alternatively it may be designed to be dropped onto fixed jacks by raising the wheels 154. The transmission shaft 140, which is permanently attached to the gear box 162, is secured to the arm 26 via the plate 150 and the sleeve 148.

The dial gauge assembly 128 is provided to measure the diameter of the casing, and enables an assessment to be made of the amount of material in the fantrack 32 which is to be removed during the machining operation. The gauge assembly 128 is set radially by initially releasing the plungers 134 and swinging the assembly to the non-operative position, where it is again locked in position by the locking plungers 134. The operating arm 128B is

urged by spring 128G so that the roller 128C contacts the setting gauge (not shown), which is inserted between a fixed setting clock 135 (Figure 2) and the roller 128C of the dial gauge assembly 128. This enables the indicator of the dial gauge to be set at zero, i.e. when the dial gauge is set to zero with the setting gauge inserted, a similar zero reading taken when measuring the fan casing radius will show that the seal has been machined to its nominal size.

As mentioned previously, the axial position of the dial gauge assembly 128 may be set with the thumbscrews 131. To do this, the dial gauge assembly 128 is moved axially until a setting block (not shown) can be inserted between a machined datum face 137 and the roller housing 128D, the thumbscrews 131 then being tightened. The gauge 128 is thus set both radially and axially relative to the engine's axes.

To check the fan casing radius, the dial gauge assembly 128 is swung to the operative position, locked in position with plungers 134 and the arm 128B is released to allow the roller 128C to contact the fan casing.

The arm can now be driven around the circumference of the fan-casing and the reading of the gauge dial will indicate variations, if any, from the correct radius.

The tool 66 is initially in a retracted state and is set for the machining operation by firstly finding the minimum radius of the fan casing. The dial gauge reading indicating this minimum radius is subtracted from the gauge zero reading, and will establish the depth of cut. The arm 26 is rotated until the tool 66 is at the minimum radius position. The tool 66 is driven by means of the motor 54 and the lead screw until the tool is aligned with the plane of the minimum radius. The tool 66 is advanced by the handle 72 until the tool contacts the workpiece. The scale reading is noted and the tool is retracted using handle 72. The lead screw 52 is operated again so that the tool is moved to one end of its total travel, where it

is stopped by one of the microswitches. The tool 66 can now be advanced using the handle 72 to set the required depth of cut. Throughout the traverse of the tool post, the cutting tool 66 follows the profile of the guide plate 88 which corresponds to the profile to be machined in the seal material. Preferably, to provide better control of the machining operation, the motor 54 is controllable to give at least two tool traverse rates, a low rate for finish machining and a high rate for roughing. A non-machining rapid traverse rate may also be provided for convenience of the operator.

The suction cleaner is operated whilst machining is in progress to extract the material removed. This prevents any waste material from entering the engine, which could be damaging, and also prevents personal contact with the waste material, which could be hazardous. When the tool 66 has stopped at the end of its traverse, the signal from the microswitch can also be used to light an indicator lamp on the cabinet 158 to alert the operator to the next operation. The machining operation is repeated, if required, with the tool 66 being advanced on each cut until the required radius and form have been achieved. The radius and form of the machined surface can be checked after each cut has taken place.

It will be appreciated that a machine tool according to the present invention provides a rapid and accurate method of machining a relatively large diameter on a work piece, in a state corresponding to that experienced by the workpiece when in use.

Although not our preferred option, it would be possible to couple the drive unit to the arm 26 via an Oldham coupling. However, this provides for only slight misalignment between the fan shaft and the drive from the drive unit, whereas the universally jointed transmission shaft 140 allows substantial misalignment. This is shown in Figure 13, where the arrow 200 indicates the Oldham coupling. Other parts are substantially as before and are

indicated by the same reference numbers. It will be seen that deletion of the transmission shaft in favour of the Oldham coupling renders the drive unit very close-coupled to the fan shaft.

Whilst the machine tool described above is particularly useful in relation to gas turbine engines, particularly large turbo-fan engines, machine tools according to the present invention can be used in relation to other types of cylindrical or circular workpieces provided with a suitable central axial location for the arm 26.

An advantage of the present inventive design is that although the arm 26 and the seal box 36 must be dimensioned to fit a particular engine type, and therefore, in general, a different one must be used for each engine type, the rest of the machine tool 10 can be made common to all engine types. For instance, the drive unit 138 can be attached to any boring arm 26, and the tool slide assembly 38 is interchangeable on all boring arms.

## Claims:-

1. A transportable machine tool, comprising an arm having mounting-means to enable the arm to be rotatably mounted in relation to a workpiece to be machined, the rotatable arm having a machining head including at least one cutting tool, cutting tool drive means to drive the cutting tool relative to the arm, and further drive means to rotate the arm relative to the workpiece.
2. A machine tool as claimed in claim 1 in which the machining head includes a slide on which the cutting tool is mounted and guide means arranged to cause the cutting tool slide to follow a pre-determined path on operation of the tool drive means.
3. A machine tool as claimed in claim 1 or claim 2 in which the machining head comprises a first slide and a second slide, the cutting tool being secured to the first slide, and the first slide being secured to the second slide, the second slide having following means engaging with a profiled face on the machining head.
4. A machine tool as claimed in claim 3 in which the profiled face is provided on a plate attached to the machining head, and the following means comprises a roller attached to the second slide.
5. A machine tool as claimed in any one of the preceding claims in which the machining head carries sealing means to form a sealed space between the machining head and a workpiece.
6. A machine tool as claimed in claim 5 including a suction cleaner and duct means connecting the suction cleaner to the sealed space.
7. A machine tool as claimed in any one of the preceding claims in which the cutting tool drive means comprises a motor secured to the rotatable arm and arranged to drive a lead screw of the machining head.
8. A machine tool as claimed in any one of the preceding claims including gauging means mounted on the rotatable arm, the gauging means being movable between an operative

and a on-operative position, and having locking means to secure the gauging means in either of said positions.

9. A machine tool as claimed in claim 8 in which the gauging means comprises a dial gauge secured on gauge support means, the gauge support means being provided with said locking means.

10. A machine tool as claimed in any one of the preceding claims, in which the further drive means is free-standing with respect to the rotatable arm, the further drive means being mounted on transportable support means.

11. A machine tool as claimed in claim 10 in which the transportable support means comprises a wheeled structure provided with stabilising means for engaging the ground during setting up and operation of the machine tool.

12. A machine tool as claimed in any one of the preceding claims, in which the further drive means includes a motor and a drive train for transmitting the drive from the motor to the rotatable arm, the drive train being disconnectable to allow separation of the rotatable arm from the rest of the machine tool.

13. A machine tool as claimed in claim 12, the drive train including a coupling constructed to allow misalignment of the axis of rotation of the rotatable arm with respect to the drive train.

14. A machine tool as claimed in claim 13 in which the coupling means comprises an Oldham coupling.

15. A machine tool as claimed in claim 16 in which the coupling means comprises a transmission shaft fitted with universal joint means at both ends thereof.

16. A machine tool as claimed in claim 12 in which the drive train includes a gear box driven by the motor, the rotatable arm being driven from an output shaft of the gearbox through the remainder of the drive train.

17. A machine tool as claimed in any one of the preceding claims in which, when the workpiece comprises the fan seal lining of a turbofan engine, the mounting means of the rotatable arm is adapted for mounting on the fan shaft of the engine.

18. A machine tool constructed and arranged for use and operation substantially as herein described, and with reference to the accompanying drawings.

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